Case for Support

Development of Particle Flow Calorimetry

1. Introduction

Particle flow is a new approach to calorimetry which aims to achieve a jet energy resolution which is more than a factor of two better than a traditional calorimetric approaches. The original motivation was the high calorimeter performance required by the detectors for the International Linear Collider (ILC) but the techniques involved will have applications elsewhere in particle physics. Particle flow calorimetry requires highly segmented detectors and sophisticated reconstruction software. The proposed work builds on the current particle flow research at Cambridge which is currently leading the field on particle flow algorithms and combines it with the RAL experience in calorimeters and pixel sensors. The award of this grant would enable the UK to maintain global leadership in this research activity and drive the design and optimisation of detectors for particle physics. Collaboration between Cambridge and RAL would broaden the scope of this work by having a closer interaction with the detector development and also extend the development of particle flow to digital calorimetry.

In this proposal two RA posts (one based in Cambridge and one based at RAL) are requested to work on the development of particle flow calorimetry. The emphasis of this proposal will be on gaining a detailed understanding of all aspects of particle flow calorimetry. The immediate application of this work will be to take a leading role in the design and optimisation of ILC detector(s), where high performance calorimetry is the critical issue for the ultimate physics performance. With Letters of Intent (LoIs) to perform detailed studies for potential ILC detectors expected in 2008 and Engineering Design Reports (EDRs) for the ILC detectors to be produced in 2010, this is the ideal time to inject effort and influence the next generation of particle physics detectors. If approved, the proposed work would establish the UK as leaders in the field of particle flow calorimeter design.

2. Particle Flow Calorimetry

Precision physics at future colliders requires unprecedented jet energy resolution of the detectors. The most promising way of achieving this is particle flow calorimetry. In the particle flow paradigm the calorimeter energy deposits from charged particles, photons and neutral hadrons are separated. The charged particle energies are well measured (essentially perfectly) from the associated track momentum and the calorimeters only used for the neutral electromagnetic and hadronic components. Particle flow calorimetry requires highly segmented calorimeters and sophisticated reconstruction algorithms to utilize the detailed calorimeter information. The required highly-granular calorimetry becomes the major cost driver in any future detector concept utilising particle flow calorimetry, and thus, a detailed understanding of how to perform particle flow calorimetry will have a major impact on the overall detector design.

The next large accelerator project after the Large Hadron Collider (LHC) is likely to be the International Linear Collider (ILC). While the location, funding and final configuration of the machine are being decided [1] there is already an active hardware R&D program [2] with more than 50M US-$ worldwide being spent per year to develop a detector for this machine. The main physics goals for the ILC are well defined and concentrate on making precision measurements, such as the properties of the Higgs boson(s) and super-symmetric particles if they exist. One of the main keys to making precision measurements at the ILC is the ability to reconstruct and identify the Gauge bosons from their hadronic decays. This requires a jet energy resolution goal of approximately $\sigma_E/\sqrt{E(\text{GeV})} < 30$ %, which cannot be achieved with a traditional approach to calorimetry. As a consequence, it is widely accepted that the main driving force behind the ILC detector design is that of energy resolution for jets as this has a direct impact on much of the physics at a high energy e^+e^- collider. The most promising avenue for achieving the jet energy resolution goal is a high granularity detector optimised for particle flow calorimetry and sophisticated calorimeter reconstruction algorithms; Particle Flow Algorithms (PFA).

2.1. Particle Flow and the ILC Detector Concepts

Three of the four ILC detector concept study groups are assuming that the particle flow paradigm with high precision tracking and highly granular calorimetry will yield the required performance. However, it has not been fully demonstrated that particle flow calorimetry can give the required ILC jet energy resolution; the best resolution achieved to date is $\sigma_E/\sqrt{E}$ (GeV) = 30 % for 45 GeV jets worsening to approximately $\sigma_E/\sqrt{E}$ (GeV) = 45 % for 200 GeV jets [3]. The current limitation is the particle flow reconstruction software. Understanding whether particle flow can deliver the ILC goal is of vital importance; if not a major rethink would be necessary. This is a pressing question as over the course of the next two to three years the detector conceptual studies are likely to evolve into experimental collaborations. In the summary talk at the recent Beijing ILC workshop it was pointed out that choice and optimisation of detector concepts cannot be made without better understanding of particle flow calorimetry and that this question needs to be resolved. It is also important to demonstrate the feasibility of these ideas using a realistic detector description including calibration effects gaps in coverage and effects like non-linearity and saturation.

2.2. Exploration of Digital Calorimetry

The fine segmentation required by the particle flow algorithm sets very stringent requirements on the calorimeter design and might be difficult to achieve with current calorimeter design. One possible option being explored by several hardware R&D groups is a digital approach to calorimetry. Instead of the classical approach of measuring an analogue quantity which is proportional to the incoming particle energy, digital calorimetry samples the particle number in a shower. From GEANT4 based simulations, the particle count summed over the calorimeter sampling layers has been shown to be proportional to the incoming particle energy (for both hadronic and electromagnetic showers). Because of the reduced cost of readout electronics, digital calorimeters can be made with finer granularity than the analogue equivalent and as result provide high resolution tracking measurements. One possibility being pursued in the UK is the used of monolithic active pixel detectors (MAPS) [4] as the sampling layer in a SiW sampling calorimeter. It is possible that this ultra-fine segmentation (down to 50 μm) does present significant advantages from the perspective of particle flow calorimetry. It leads to more compact calorimeters and is potentially easier and cheaper to manufacture and leads to a reduced data rate.

2.3. Particle Flow Algorithm Research at Cambridge

To date the most sophisticated and best performing implementation of particle flow reconstruction is the PandoraPFA algorithm developed in Cambridge by M.A. Thomson. The algorithm takes advantage of the ability to track particles through the calorimeters. It should be emphasised that this reconstruction goes far beyond a simple clustering algorithm and includes topological association of clusters, photon identification, and an iterative procedure to re-cluster densely populated regions of the detector. This work has been widely reported [3,5,6,7,8] and represents the state-of-the-art in the worldwide research into particle flow calorimetry. As an example, Figure 1 shows the particle flow reconstruction of a 100 GeV jet and the energy resolution performance for 45 GeV jets. At the recent LCWS07 meeting in DESY, the results from PandoraPFA demonstrated for the first time that the particle flow approach to calorimetry with the current ILC detector concepts is likely to be able to meet the jet-energy resolution requirements for physics at the ILC. These results, along with the related detector optimisation studies, were widely presented at this meeting and in the parallel review of calorimetry. This research has reached the stage where progress is limited by lack of effort rather than lack of ideas.

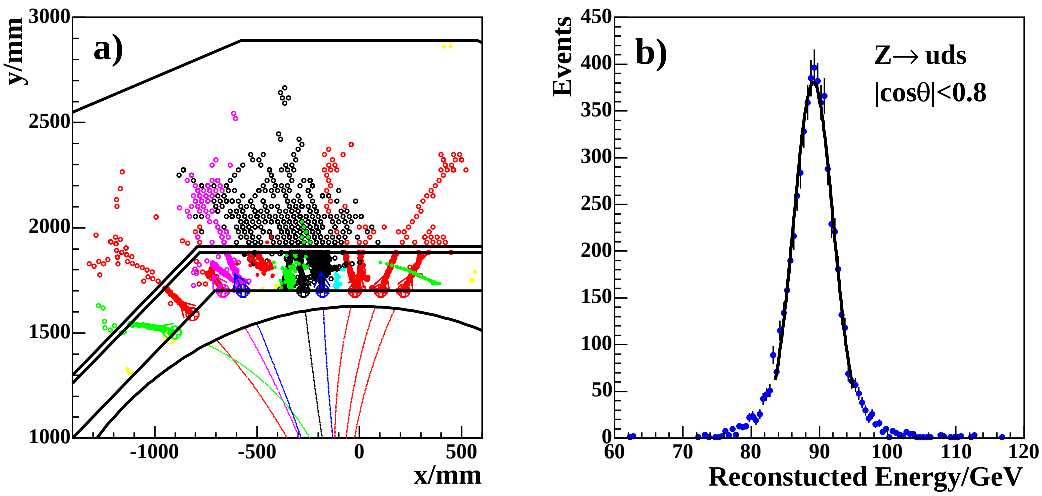

Figure 1: (a) An example of the particle flow reconstruction of a 100 GeV jet using the PandoraPFA algorithm; (b) the distribution of the total reconstructed jet energy in the decays of Z to light quarks (uds) at $\sqrt{s}$ = 91.2 GeV.

2.4. Digital Calorimetry and Particle Flow Algorithms at RAL

M. Stanitzki has recently been employed at RAL to undertake R&D on calorimetry for the ILC and to establish a physics group to exploit the ILC physics potential. In the last months he has set up the appropriate ILC software and equipped the development laboratory for evaluation of MAPS based electromagnetic calorimeter prototypes. A recent progress report on MAPS-based calorimeters can be found here [9].

To date, all existing particle flow algorithms have concentrated on reconstructing fine-grained analogue calorimeters. Utilising the extremely fine segmentation of digital calorimeters with a particle flow algorithm could significantly improve the energy resolution. This can be seen in Figure 2 which compares the same event reconstructed using analogue and digital techniques. There has already been a feasibility study undertaken by the main investigators to understand how to adapt the existing PandoraPFA algorithm for high granularity digital calorimetry. In principle, there seem to be no problems although a number of different techniques will need to be developed to take full advantage of the very high segmentation and only at this stage will it be possible to compare the particle flow performance of digital and analogue options.

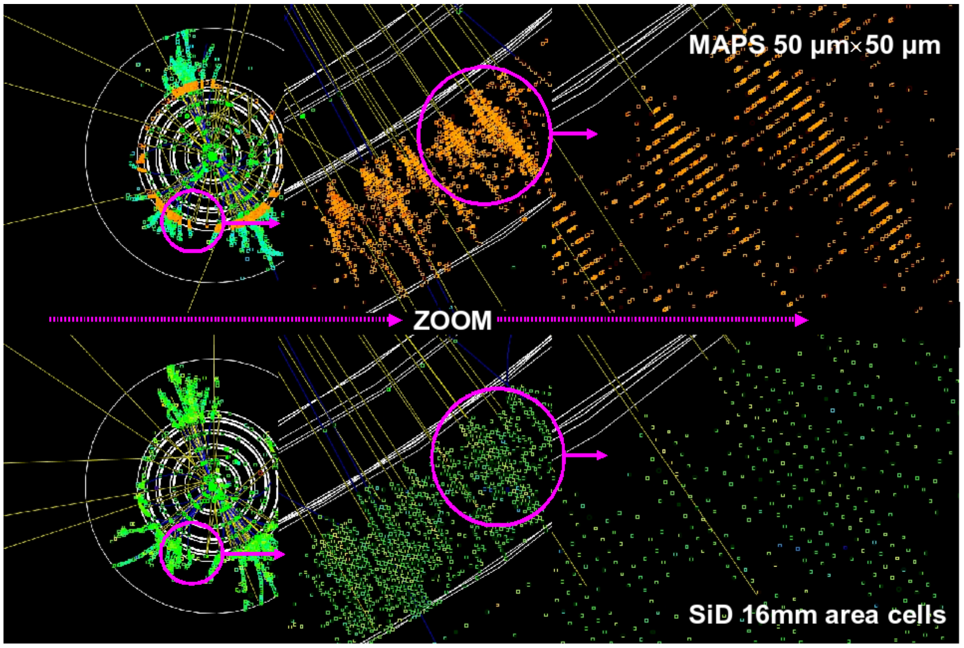

Figure 2: Comparing the resolution of a Digital Electromagnetic Calorimeter using MAPS (top) and a conventional Analogue Electromagnetic Calorimeter (bottom). The high granularity of the MAPS approach can be clearly seen.

3. Project Overview

Although the concept of particle flow calorimetry is not new, the sophisticated particle flow reconstruction of highly segmented calorimeters is at a relatively early stage. Through M. Thomson's work, the UK is currently leading this research worldwide. Additional effort is required now for this work to develop further, particularly as the PandoraPFA reconstruction is becoming more widely used for different detector designs by ILC groups worldwide. Furthermore, it is becoming increasingly clear that particle flow reconstruction involves much more than calorimeter reconstruction alone – the study of how to use of the central tracking and vertex detector information requires additional effort. At this time, there is a clear opportunity to build on this work and maintain the UK's position as the global leader in particle flow calorimetry. The main strategic goals of the proposed project are:

- Maintain and extend the UK's leadership in particle flow calorimetry
- Broaden the base of the UK knowledge in particle flow calorimetry and strengthen the collaboration between the STFC laboratories and the university groups
- Fully develop and understand particle flow calorimetry and use this knowledge in the optimisation of the overall design of the ILC detector(s)
- Study the application of particle flow to digital calorimetry in general and study the potential for digital calorimetry at the ILC

3.1. Timeliness of the Proposed Research

Whilst the study of particle flow calorimetry is of wide-ranging academic interest, it is important to emphasise that the proposed research forms an essential part of the work towards the ILC detector design. The ILC experimental collaborations will evolve from the current detector concept groups on the timescale of approximately two to three years and the research programme proposed here needs to be pursued now. Letters of Intent to write one of the two ILC Detector EDRs will be submitted in the summer of 2008 with the detector EDRs due in 2010. The proposed research programme offers a real opportunity to lead the development of particle flow calorimetry and to play a leading role in design and optimisation of calorimetry in the post LHC era.

4. Project Plan

It is only recently that the 'in-principle' benefits of particle flow calorimetry have been demonstrated [3]. To fully realise the potential of particle flow calorimetry will require effort beyond what is currently available. This is necessary to develop the optimal reconstruction utilising all aspects a detector (not just the calorimeters). In addition, new effort is required to develop techniques to: incorporate realistic detector geometries; take into account efficiencies and dead space; devising a calibration strategy; and to understand the cost/performance optimisation for a particle flow detector. The two RAs would develop the ideas and techniques in the PandoraPFA algorithm into a particle flow reconstruction package for more general application. This especially includes the algorithm development and optimization for digital calorimetry. The main goals of the project are to understand how to achieve the best possible performance with PFA and to understand the ultimate limiting factors. The results would then be applied to the optimization of the ILC detector design.

4.1. First Year of the Project

The first year of the project would concentrate on the development and optimisation of particle flow reconstruction. The work would be performed in the existing ILC software and simulation framework which provides sufficient flexibility to study different calorimeter and detector designs. In the initial ramp-up phase the RAs would become familiar with this framework and the existing particle flow reconstruction in PandoraPFA. After this initial ramp-up phase, there are a number of specific goals:

- Adapt the PandoraPFA algorithm to work with different calorimeter concepts and detector design.
- Extension of the algorithm to take advantage of digital electromagnetic and hadronic calorimeters.
- Algorithm development and optimisation; PFA is relatively new and there are many open questions, e.g. adaptively utilising multiple clustering strategies, the optimal use of the tracking information to guide the calorimeter reconstruction, and the optimal identification of neutral hadrons.
- Study the impact of particle identification in improving particle flow performance, e.g. π^0 finding, improved photon identification and the reconstruction of kinks and V^0s in the tracking chambers.
- Documentation of the algorithm/software package for external use.

4.2. Second Year of the Project

In the second year of the project the emphasis would shift to the development of new ideas and the application of the gained understanding of particle flow to the optimization and choice of ILC detector design. In addition we would like to study the possibility of using a high granularity digital calorimetry as a shower pre-sampler in the first few radiation lengths where shower widths are much narrower than the Molière radius. The specific goals would be:

- Implement track finding and fitting in the calorimeter to improve the performance by tracking particles before showering. This technique may be important to provide seed tracks for the track reconstruction in a Silicon central tracker.
- Study the possibility of reconstructing the missing energy component in jets by identifying $K^{\pm}\rightarrow\mu^{\pm}\nu$ decays in the tracking chambers and identifying semi-leptonic decays of heavy quarks in the vertex detector.
- Implement a hybrid electromagnetic calorimeter (ECAL) using a very fine grained pre-shower detector using digital calorimetry technology and an analogue ECAL for the remaining layers. This could provide an attractive solution for a particle flow detector in terms of cost and performance.
- Conduct a detailed PFA performance study jet energy resolution, taking into account the detector B-field, the calorimeter depth, the optimal choice of longitudinal and transverse segmentation of ECAL/HCAL, the impact of the track reconstruction, and the impact of the detector material.
- Release the generic PFA package.
- Lead the detector optimisation studies for the ILC particle flow detector(s) that will be developed for the ILC detector Engineering Design Reports (EDR).

4.3. Third Year of the Project

In the third year, the focus of the proposal becomes oriented towards studying a realistic detector design including material, dead areas and backgrounds. The results of these studies will have a strong impact on the Detector EDRs.

- Extend the studies to a realistic detector design. Study the impact of material, such as conversions and showering in the tracker end-plate, and related reconstruction strategies as well as the impact of dead detector elements and detector noise/machine backgrounds. This will establish how PFA will perform with a complete and realistic detector description.
- Study and understand the sensitivity of the results to the simulation of hadronic showers.
- Study the impact of forward calorimetry and forward tracking on the particle flow performance.
- Make leading contributions both to the design and optimisation of the ILC detector concepts and to the ILC detector EDRs.

A project timeline for the entire 36 month duration is shown in Figure 3 indicating the approximate length of time the RAs would be expected to spend on each activity. It should be noted that many of the above issues are not confined to the calorimeters; the whole of the detector design has an impact on particle flow performance. Addressing these questions from the point of view of particle flow will form a significant part of the work in this proposal. In addition to the academic interest in furthering the understanding of particle flow calorimetry, this work would be of immediate use for the ILC calorimetry community and would place the UK at the heart of the design of the detector concepts.

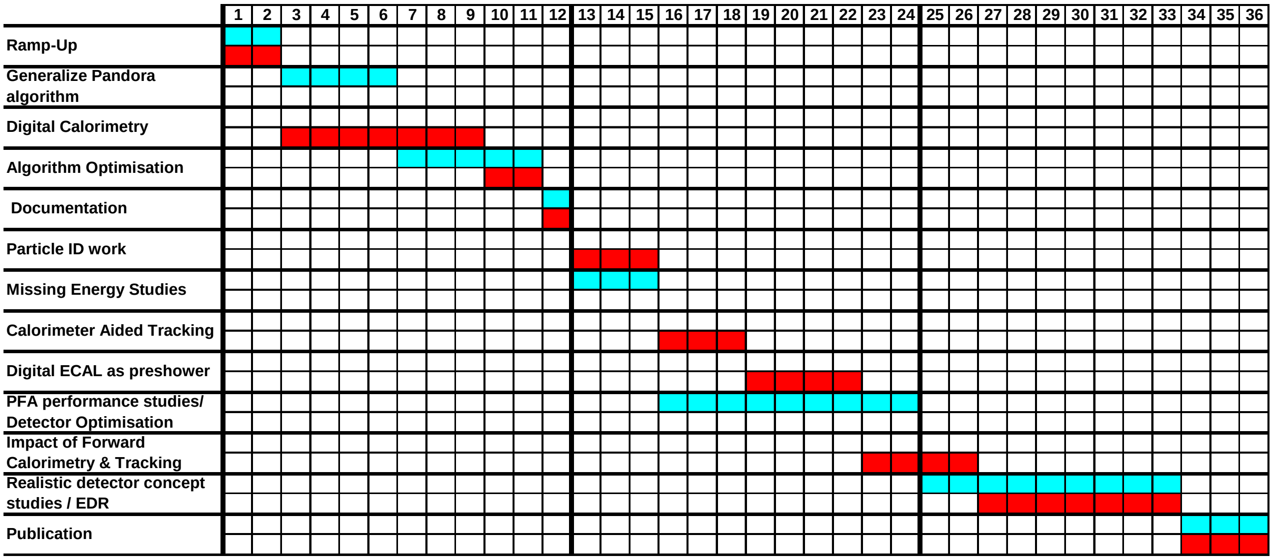

Figure 3: The project plan for the two RA positions at Cambridge (light blue) and RAL (red) for the 36 month programme.

4.4. Deliverables/Milestones

There are a number of specific deliverables and milestones.

End of Year 1

- The release of a generic and powerful particle flow algorithm with support for different technologies and detector concepts.
- Publish an evaluation of the jet energy resolution achievable with particle flow calorimetry.
- Development of particle flow calorimetry for digital calorimeters and a first evaluation of the potential benefits.
- Presentation of results at major conferences and workshops.

End of Year 2

- Detailed studies of particle flow performance and a comparison of analogue and digital calorimetry with results presented at major conferences and workshops.
- Evaluation of the potential benefits of a hybrid calorimeter (digital pre-shower/analogue ECAL).
- Cost/performance optimisation studies for the ILC detector concepts.

End of Year 3

- Publication of the definitive study of particle flow calorimetry, discussing techniques, performance and the aspects of the overall detector design which are most relevant to particle flow calorimetry.
- Take a leading role in the writing of the ILC detector EDRs.

5. Resources

We are requesting two RA positions, one located at RAL and one located at Cambridge. As a part of this grant is going to be awarded to STFC RAL, which is not part of the dual support system, the grant is expected to cover 100 % of the costs. The costs associated with Cambridge post are calculated at 80% fEC. In order to achieve the goals outlined above, the following resources are requested for the three year duration of the project:

- Two RAs, one at Cambridge and one at RAL. Cambridge uses the first real spline point above the minimum (point 41) to calculate the salary, while RAL is using the mean value of STFC band 5 for the salary calculation.
- Travel Budget £7000 per year, £21000 in total. This is to allow the RAs to attend international meetings and workshops and to present results at conferences and ILC detector concept meetings. It would also be expected that the two RAs would work as a team which would involve face-to-face meetings at RAL and/or Cambridge. The travel costs are calculated as follows: travel within the UK (£1000 p.a.), two international conferences (£2000 p.a.), two trips to the US/Asia (£2000 p.a.) and four trips within Europe (£2000 p.a.).
- Computing: the two RAs will require a laptop and we request a total of £3000 for the entire period of the project.
- Under fEC additional funding is requested for M. Thomson's at the level of 2 hours per week to specifically cover direct management and supervision of the RAs. The time will be made available by a commensurate reduction in college teaching duties where the M. Thomson currently commits significantly more time than the minimum required under the terms of his College Fellowship.
- Contingency: we consider the major risk to this project as being able to recruit and retain RAs of sufficient quality. For this reason the RAL based RA is costed at the mid-point of the STFC band 5 to allow flexibility in recruitment. For this reason we request a contingency of £3600 to allow for the possibility of recruiting the Cambridge RA at the next higher salary point (point 42).

5.1. Project Effort

Table 1 shows the breakdown of staff effort funding under this proposal by calendar year. We anticipate that the new posts would start on January 1st 2008. Also shown is the breakdown of the cost to STFC by year of the project. Table 2 provides a summary of the total costs of the project which is almost entirely the costs associated with the two new posts.

Participant	**Group**	**Position**	**Fraction on Project %**			**Cost to STFC £**		
			2008	2009	2010	2008	2009	2010
Dr M.A. Thomson	Cambridge	Reader	10	10	10	4744.15	4744.15	4744.15
Dr M. Stanitzki	RAL	Staff	10	10	10	0	0	0
RA (Cambridge)	Cambridge	RA	100	100	100	62,805.60	63,595.20	65,244.80
RA (RAL)	RAL	RA	100	100	100	82,523.00	83,688.00	84,853.00
Contingency	Cambridge					1,200.00	1,200.00	1,200.00
Travel						6,300.00	6,300.00	6,300.00
Equipment						2,700.00		
Total Cost						160,272.75	159,527.35	162,341.95

Table 1: The project participants 36 month programme by calendar year.

	Cambridge	STFC/RAL	Total
Staff Effort	80,957.60	112,935.00	193,892.60
Investigators	8,328.45	0.00	8,328.45
Estate	32,510.40	21,324.00	53,834.40
Indirect	84,081.60	116,805.00	200,886.60
Staff Total	£ 205,878.05	£ 251,064.00	£ 456,942.05
Equipment	0.00	0.00	0.00
Travel	8,400.00	10,500.00	18,900.00
Other	1,200.00	1,500.00	2,700.00
Contingency	3,600.00		3,600.00
Total	£ 215,478.05	£ 263,064.00	£ 482,142.05

Table 2: The total cost for the project, split between Cambridge and RAL. For Cambridge the costs are calculated at 80 % of fEC and for RAL at 100% of fEC.

6. Summary

Particle flow calorimetry is a combination of high granularity detectors and sophisticated reconstruction software. Through the effort at Cambridge, the UK is leading the field in the development of particle flow reconstruction. RAL has considerable experience in calorimetry and is at the forefront of research into highly granular digital calorimetry based on MAPS. Particle flow calorimetry enables jet energies to be reconstructed with an energy resolution of up to a factor two better than conventional calorimetry. At future colliders this improvement in jet energy resolution may significantly enhance the physics performance of the detector. We are requesting support for two new RA posts, one at Cambridge and one at RAL to:

- Undertake a research program which could define particle flow calorimetry.
- Perform the definitive study for Particle Flow algorithms.
- Maintain the UK's position as a one of the leaders in Calorimeter R&D and design.
- Define the role of digital calorimetry as a viable alternative for the ILC.
- Provide a large amount of added value to UK investment in Calorimeter R&D.
- Strengthen the collaboration between the STFC laboratories and the university groups.

The work in this proposal is timed to coincide with an important phase in the development of the detectors for the ILC; it is likely that detector collaborations (or at least proto-collaborations) will form on this timescale. As such this proposal would strengthen the UK's strategic position within the ILC detector program by taking a leading role in the definition of the detector design. For a relatively modest investment the UK will maintain and develop its leadership in particle flow calorimetry at this important time.

Appendix

Scientific Excellence

The concept of particle flow calorimetry has been around for a number of years. However, it is still not clear how particle flow reconstruction should be approached and what calorimetric performance can be obtained. This is a new area of research and there are many open questions. The ideas and techniques developed by M. Thomson in the PandoraPFA approach to particle flow are currently at the forefront of this area of research. The collaboration between Cambridge and RAL will build on this work and M. Stanitzki's expertise in the development of digital calorimetry. The proposal programme of work aims to provide the definitive study into particle flow calorimetry. This is work is of academic interest and is central to the design of the detectors at the ILC. The award of a two RA positions would maintain the UK's leadership in particle flow calorimetry and enable these ideas to be fully exploited in the development and optimisation of the ILC detector(s).

Objectives

The objectives and deliverables of the project are detailed in the Case for Support.

Awareness and context

The concept of particle flow calorimetry has been around for a number of years; a number of the LEP collaborations employed a primitive form of particle flow to reconstruct jet energies, however the performance gains were only modest due to the low granularity of the detectors. The research into high performance particle flow calorimetry using highly granular detectors is at a relatively early stage. Until very recently it had not been demonstrated that particle flow could provide good jet energy resolution for jets of above 100 GeV. Through the work performed at Cambridge, it is becoming accepted that particle flow is a viable option for future collider detectors. The development of particle flow calorimetry is central to the design of the ILC detectors. The three year timescale of this proposal and the resources request are sufficient to perform an in depth study of particle flow calorimetry and the link to very high granularity digital calorimetry.

Competing Experiments

The work on the development of particle flow calorimetry performed at Cambridge is leading the field in terms of performance and the sophistication of techniques employed. There are four other groups actively developing particle flow calorimetry. For the high energy jets of interest at future colliders, i.e. jet energies of greater than 100 GeV, the performance of the PandoraPFA approach is about a factor of two better than achieved elsewhere. RAL with its background on sensor design is a leader in the field of digital calorimetry both for sensors and reconstruction.

STFC Science

The proposed research aims to maintain the UK's leadership in the development of particle flow calorimetry. This is likely to have applications in future collider detectors. In the immediate future the main application is likely to be at the ILC. The detector concepts are designed for particle flow calorimetry. However, to date the particle flow paradigm has yet to be fully demonstrated. The majority of issues related to the overall design (as opposed to sub-detector design) of an ILC detector are related to the performance of particle flow calorimetry. This proposal, will extend the current studies to more generic calorimeter design (including those of the SiD and GLD concepts), and will place the UK in a central position within all detector concepts at a time when experimental collaborations are forming. The potential strategic benefits to STFC and the UK HEP community are significant.

Leadership/Management and Suitability of Institutions

The overall project would be led by Dr Thomson, with Dr Stanitzki leading the work in the development of digital calorimetry. There is a strong synergy between the research interests and strengths of the Cambridge and RAL groups. Cambridge is at the forefront of the worldwide research into particle flow. Furthermore, members of the Cambridge group are leading a number of related software and simulation activities in the context of the ILC and possess a great deal of experience of performing precision physics measurements. The RAL group brings a wealth of knowledge in the development of detectors for large collider experiments and are leading the current development of MAPS sensors which could form the basis of a digital electromagnetic calorimeter. Both Dr Thomson and Dr Stanitzki and have a strong background in e^+e^- physics within the OPAL and DELPHI collaborations, respectively.

Track Record: Dr M.A. Thomson

Dr Thomson is currently working on MINOS and the ILC/CALICE and previously worked on the OPAL collaboration as a CERN staff physicist. He has a proven track record in physics analysis and the development of novel reconstruction and analysis techniques.

Opal: Dr Thomson played leading roles in the OPAL programme of precision electroweak measurements of the properties of the Z and W bosons. He made significant contributions to the measurements of: Z lineshape, tau-pair forward-backward asymmetries and tau polarization, W mass, W production cross sections and decays, limits on anomalous W and Z quartic couplings. In the context of the tau polarization measurement he developed a novel image processing application of maximum entropy to calorimeter reconstruction. He held leadership roles within OPAL and the wider LEP community.

MINOS: Within MINOS Dr Thomson led the atmospheric neutrino study and developed reconstruction and analysis techniques, including a study of a semi-digital approach to reconstructing hadronic showers in MINOS. He is currently working on a novel approach to the search for $\nu_\mu \rightarrow \nu_e$ oscillations. He currently holds a number of leadership roles including being the chair of publications committee and the UK MINOS spokesperson

ILC/CALICE: Dr Thomson has been central to the development of particle flow calorimetry as applied to the ILC. To date, most of this work has concentrated on calorimeter reconstruction within the context of the CALICE R&D collaboration. He has applied this work to ILC detector design and optimisation studies for the LDC and GLD detector concepts. He holds a number of leadership roles within international ILC community concentrating on software reconstruction and physics simulation in the context of ILC detector design.

Publication Summary: Dr Thomson is an author of over 350 publications, a full list of publications can be found at http://www.hep.phy.cam.ac.uk/~thomson/publications/pub.html. In the period Jan

2004-Jan 2007 he has been the author on 25 refereed publications, 8 technical reports and 6 first author technical reports. A full publication list is included in the Je-S submission.

Track Record: M. Stanitzki

Dr Stanitzki is currently working on ILC/CALICE and previously worked on the DELPHI experiment for his Ph.D and on the CDF experiment as a postdoctoral fellow for Yale University. He recently joined RAL as a Staff scientist working on ILC detector R&D for CALICE.

DELPHI: Dr Stanitzki was the convener for invisible and flavour-blind Higgs decay searches with the DELPHI detector at LEP. He also made contributions to the DELPHI simulation effort at Karlsruhe, producing large simulation sets for Higgs searches.

CDF: At CDF, Dr Stanitzki was central to the Silicon Detector Project. He became leader of the Silicon Project in 2005, being responsible for the entire Silicon System at CDF. He also contributed to a Universal Extra Dimension search and co-developed a kinematic fitting package.

ILC/CALICE: Dr. Stanitzki has joined the CALICE effort at RAL in November 2006 and has been working on the design for MAPS sensors that are suitable for ILC digital calorimetry. He also works on the reconstruction software for this type of calorimeter and has already collaborated with Dr. Thomson in order to include digital hits information into the PandoraPFA algorithm.

Publication Summary: Dr Stanitzki is the author of 168 publications, in the period of January 2004-Jan 2007 he has 71 refereed publications, 4 technical reports and 3 technical reports as first author. A full publication list is included in the Je-S submission.

Collaborative Projects

At the time of the writing the ILC detector community is taking the first steps towards the setting up a more formal organisational structure which will ultimately lead to the formation of experimental collaborations. Although this proposal is intended to provide a generic study of the potential of particle flow calorimetry, it will be immediately applicable to the ILC detectors and this work will strengthen the place UK physicists in the ILC detector community. To some extent this has already happened: Dr Thomson has led the initial studies of the optimisation of the LDC detector concept and is a convenor of the ECFA working group into the overall ILC detector performance and optimisation. Dr. Stanitzki is the UK contact for SiD in terms of calorimetry.

Long Term Objectives

The objectives of this proposal are to perform the definitive study of the techniques required for particle flow calorimetry. Beyond the three year period of this proposal, the knowledge and experience gained would be used drive the design of future particle flow based detectors and will undoubtedly be a major influence on the design of the ILC detectors.

Technology Transfer and Development

Particle flow calorimetry is almost certainly only applicable to HEP, however the techniques developed may have applications in a wide range of future collider experiments.

Training and Outreach

Besides the presentation of his results within the project, the RAs will be expected to present the project and the field to a wider audience; in addition the RAs would be expected to give general lectures on calorimetry and the ILC at Summer schools. Furthermore, simulated physics events reconstructed with the particle flow approach provide an ideal basis for fourth year undergraduate projects since the reconstructed events are in the form of a list of particles. Three such projects have already been run successfully as part of the Cambridge Part III M. Sci. physics course.

Cross-Council

Particle flow development is very much focussed on specific problems in particle physics, and applications outside this field seem unlikely.

Beneficiaries

This research will immediately benefit the community that works on the International Linear Collider (ILC), since the work on particle flow algorithms is a key issue for the detector design. At the current stage of design, 3 of the 4 proposed detector designs for the ILC are built around the particle flow approach. Also the hardware R&D program for digital calorimeters would benefit from the results of this project. Outside of the ILC community, there are no obvious beneficiaries, since particle flow is clearly aimed for the ILC environment. However, the results could influence the way the reconstruction is performed at the Large Hadron Collider (LHC), given it is technically feasible. It may have some influence on the design of the upgrades of ATLAS and CMS that might take some of the results obtained into account for their detector upgrades.

The UK particle physics program as a whole would certainly benefit from having a leadership role in this kind of research, as it would also strengthen its position in future ILC detectors. Outside of particle physics, there is no obvious application for particle flow calorimetry.

Risks

The main risks associated with this project are in the employment and retention of the RAs as this could introduce delays into the proposed plan of work. This is mitigated both by the attractiveness of the project which is genuinely new and the track record of both investigators. The relevance of the work to the ongoing development of the ILC detectors would allow the RAs to obtain a high profile within this international community. In addition, the salary of the RA based at RAL is calculated at the mid-point of STFC band 5 and we request a contingency of £3,600 to cover the potential cost of having to employ the Cambridge RA at one higher salary point. The main external risk is the dependence of the project on external software packages, such as the detector simulation and reconstruction framework. This is mitigated by the fact that the existing framework is sufficient for most of the proposed work and the low likelihood of the end of the development of the ILC software frameworks.

References

[1] ILC Reference Design Report, http://media.linearcollider.org/rdr_draft_v1.pdf.

[2] ILC Detector Concept Report, http://www.desy.de/~behnke/dcr/Detector/DCR_100607.pdf.

[3] M.A. Thomson, "Progress with Particle flow", to appear in the proceedings of LCSW07, DESY, June 2007.

[4] R. Turchetta et al. "A monolithic active pixel sensor for charged particle tracking and imaging using standard VLSI CMOS technology", Nucl. Instr. and Methods A 458 (2001).

[5] M.A. Thomson, "Particle Flow Calorimetry at the ILC", Proc. Of HSSW06, Fermilab, September 2006, AIP Conf. Proc. 896, (2007), 217-224.

[6] M.A. Thomson, "Towards full simulation of ILC Physics", ECFA ILC Workshop, Valencia, November 2006.

[7] M.A. Thomson, "A Topological Approach to PFA", in the proceedings of LCWS06, Bangalore, March 2006.

[8] M.A. Thomson, "Particle Flow Calorimetry", ECFA ILC Workshop, Vienna, November 2005.

[9] A.M. Magnan, M. Stanitzki *et al.*, "A MAPS-based Readout of an Electromagnetic Calorimeter for the ILC", to appear in the proceedings of LCSW07, DESY, June 2007.